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The Use of Virtual Reality in Mindfulness Meditation

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***Abstract*—Virtual Reality (VR) is widely used in different areas of research in psychology. Its use seems irreplaceable since it allows the simulation of many previously unreachable interactions in laboratory settings. In our research, we designed an environment to facilitate meditational training. We tried to prove that VR can support mindfulness through immersion. We also hypothesized that mindfulness meditation would show significantly higher results than relaxation on mindfulness-related constructs such as decentration and curiosity. The same effect would also be visible on positive mood or social skills questionnaires. A total of 80 participants took part in the research. However, the results did not support our hypotheses. Whether meditation or relaxation took place, with or without VR, none of these conditions seemed to differ significantly from one another. The psychometric issues related to the research are discussed as well as the qualities of VR that could have inhibited the effects of immersion, such as real world similarity, level of abstractness of the virtual environment, landscape, and virtual enhancement of transcendence.**

Keywords-Virtual Reality; Virtual Environment; meditation; mindfulness.

I. INTRODUCTION

The potential of Virtual Reality (VR) in science has been explored in various fields, e.g., in understanding clinical aspects of fear and anxieties [3] by provoking certain desired states in a safe laboratory environment. It is a widely used tool in therapy – for example, in short-term pain distraction [18], or in anxiety treatments, where VR is used as Virtual Reality Exposure Therapy (VRET) [34], as well as in Post-Traumatic Stress Disorder (PTSD) therapy [10] or in the treatment of arachnophobia [5]. In the current research, we would like to examine whether VR has the potential to be successfully used to enhance a meditative experience. In this article, "mindfulness", "meditative experience" and "meditation" will be used synonymously for ease of reading. However, we are aware of the complexity of what meditation actually is and that "mindfulness" represents only one type of a meditation-related state.

II. VR IN CONTEMPLATIVE STUDIES

VR can create a stressful environment that is not accessible in real-world ethical studies, e.g., an immersive VR environment can be used to imitate a train station hit by several explosions [7]. By doing this, it can elicit fear, anxiety or, in general, a difficult emotional state under stress. In this way, the influence of meditation on emotions and processing stress can be checked in ethically approved, albeit stressful conditions. The aforementioned study confirmed a less anxious response to stressful stimuli in a group of meditators who underwent an 8-week-long meditation course prior to the experiment. However, it does not prove the utility of VR in enhancing an alternative state of mind.

VR has been checked as a tool supporting relaxation while meditating. For example, VR can be used in connection to neurofeedback to check the impact of meditation on a group of chronic pain patients [15]. As the patients became more relaxed, the view of a forest in VR changed to a less foggy, clearer, sunny and green image. This was not immersive VR though, as a stereoscopic VR viewer was used. Later in this article, we will describe the difference between relaxation and meditation in more depth, and the relation to relaxation in meditation.

Another example of a VR-meditation connection is a study using neurofeedback (specifically, electroencephalography, EEG) for focused attention and body-scan [24]. The study proves, amongst other things, that immersive VR, with or without neurofeedback, can give significantly better results in questionnaires related to meditation (self-reflection and relaxation) than the control conditions, in which the participants could observe the same view as the experimental group, albeit on a computer screen. As the VR design is crucial to this kind of research, it seems important to mention that the authors decided to keep the environment as simple as possible (the leaves on the trees were represented as triangles; the sky was left cloudless). The study proved immersive VR to be of some use as a meditation-enhancement tool even though the participants had to sit still.

Why would VR be effective in enhancing meditation? One of the most common types of meditation, mindfulness, has been researched for almost 30 years and started with an 8-week long meditation training program known as Mindfulness-Based Stress Reduction Program designed by Jon Kabat-Zinn [22]. Mindfulness meditation was conceptualized and later proved to work as an emotion processing strategy, along with suppression and positive reappraisal [6]. It has been commonly used as a relaxation method as well as part of therapeutic treatments [13][14]; it has also been shown to influence compassionate and empathetic thinking [4], stereotypical thinking [36], prejudices [27][28] and conflict studies [1]. Since VR has already been successfully shown to enhance meditative

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experiences, we decided to replicate this result using a brief meditation training session. We were interested in examining whether such a complex state as mindfulness meditation [16] can be influenced by a simple mindfulness training session and enhanced by a basic immersive VR environment. We wanted to explore in more depth the possibilities that VR gives to facilitate meditation, as well as try to identify any obstacles that modern technology meets when facing an alternative state of mind. It was interesting for us to see whether a brief training session gives any results as it did in several previous studies (see: [27] and [28], as examples).

III. RESEARCH HYPOTHESES

In our study, we decided to combine Virtual Reality with mindfulness meditation and compare the effects of both mindfulness and relaxation with or without VR. The goals were: 1) to investigate the possibilities of using Virtual Reality in meditative states (mindfulness meditation only) with the hypothesis that VR would enhance relaxation and detachment from the surrounding environment which may facilitate the experience for the meditators. This would be mirrored by higher scores on the subjective well-being scales, as well as on the meditation-related scale, especially in the experimental (mindfulness) group with VR; 2) to compare the influence of a short meditation vs. relaxation training session on subjective well-being and mindfulness-related states (such as decentration and curiosity of one's emotions and thoughts) with our hypothesis being, the experimental mindfulness groups would feel happier and more open to their thoughts and emotions after the training session than the relaxation groups; 3) to our knowledge, there is yet no study relating mindful meditation and VR with social processes, hence we decided to compare the influence of short meditation or relaxation sessions in social processing (such as empathic thinking, or seeing humanity as one in general). Our hypothesis was that the experimental mindfulness group would present more empathic thinking and would identify with all humanity more than the relaxation group.

IV. METHOD

A) VR Environment

The immersive VR environment used for the study was prepared by the authors in Unity 2018.3.8f1. The environment was created to imitate the natural surroundings as reliably as possible using the accessible assets. Figures 1 and 2 present the final form of the environment prepared for the study. The concept of the 'meditation island' was to facilitate achievement of meditative states, hence it was supposed to be calming, imitating a mountain lake view, enhancing the self-reflective nature of meditation. Participants could also hear sounds of a forest (including various bird species singing) regardless of their experimental group: those who did not meditate in VR had headphones with the background music on. The hardware that was used in the study was VR HTC Vive Pro with Stereo AudioTechnica mx 20 headphones, connected to an Intel Xeon based PC with the Nvidia GTX 1070 graphics card.

Figure 1. The mountain lake view of the 'meditative island'; the front view of the virtual environment.

Figure 2. The view on the mountains. The back view of the virtual environment.

B) Experimental conditions

The experiment was conducted using the between-subjects design. Participants were divided into four groups (2x2 design) with or without VR (VR, No VR); with mindfulness meditation instructions or simple relaxation instructions (meditation vs. relaxation group). The design is illustrated in Table I. Participants were randomly assigned to a certain group at the beginning of each study. Subsequently, they sat on a chair in an empty room, facing the same direction both in real and in VR, with VR hardware on, or with headphones only. Before starting the software, participants in all groups listened to the instructions delivered by professional mindfulness trainers. Under mindfulness conditions, participants were asked to observe their thoughts and emotions in a non-judgmental manner and let them go, as they would not be related to them, observing their bodies and breath. Under relaxation conditions, participants were taught to tense and relax certain body muscle groups step by step. After these instructions, participants were asked to continue these tasks during a VR experience or listening to the sounds of forest, which took exactly 15 minutes. Participants could freely observe the environment if they wished to. Afterwards, they were asked to fill in the questionnaires (listed below) and had time to ask questions. Figure 3 briefly outlines the study design.

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TABLE I. EXPERIMENTAL CONDITIONS DESIGN

	With VR	Without VR
mindfulness meditation	Group 1 (N = 20)	Group 2 (N = 20)
relaxation	Group 3 (N = 20)	Group 4 (N = 20)

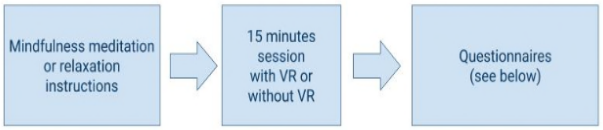

Figure 3. The study design.

C) Measures

In order to check our hypotheses, we decided to use several questionnaires translated into Polish: the Toronto Mindfulness Scale to measure the state of mindfulness meditation, the Positive Orientation Scale, the Depression Anxiety Stress Scale, the Satisfaction With Life Scale to check the influence of meditation on mood, and the Interpersonal Reactivity Index as well as the Identification With All Humanity scale to check the social processes.

Toronto Mindfulness Scale (TMS; meditation-VR group, mean = 3.60, SD = 0.48, relaxation-VR group, mean = 3.60, SD = 0.60, meditation-no VR group, mean = 3.59, SD = 0.50 and relaxation-no VR group, mean = 3.36, SD = 0.48). Since we did not use any objective measure of mindfulness as a state, we decided to use the Polish translation of the commonly used Toronto Mindfulness Scale prepared by one of the authors. The scale has been developed as a questionnaire measuring mindfulness as a state and consists of 13 questions with two subscales: Decentering and Curiosity [25]. The original scale had satisfactory results: high internal consistency as well as positive correlations with scales measuring life satisfaction and happiness, and negative correlations with scales measuring ruminations and anxieties. We used a Polish translation of the test with 13 questions grouped into two subscales with responses formed in a Likert scale from 1 („I definitely disagree with this statement") to 5 („I definitely agree with this statement"), as in the original version. We decided to use the TMS as we needed a measure to understand the potential differences between relaxation and mindfulness. The TMS is a commonly used questionnaire [35] that has been used in a pilot study and translated into Polish by one of the authors in collaboration with the Department for Social Sciences at the Pontifical University of John Paul II, , and trialed on a sample of 300 participants via an online research questionnaire using confirmatory factor analysis consisting of two subscales. In the current research, the internal reliability was checked using Cronbach's Alpha (α = 0.75) which is a satisfactory level.

Positive Orientation Scale (POS; meditation-VR group, mean = 3.59, SD = 0.64, relaxation-VR group, mean = 3.63, SD = 0.54, meditation-no VR group, mean = 3.59, SD = 0.81, and relaxation-no VR group, mean = 3.59, SD = 0.66). The scale has been translated into Polish and proved to have significant internal validity and was well correlated with similar measures within the Polish population [29]. We used it to compare the results of the effects of meditation and relaxation on the TMS with the general tendency to stay positive-oriented. POS in a shorter 8-item version is a construct measuring self-esteem, life satisfaction and optimism within one factor. Our hypothesis was that those who score higher on the TMS would have a general tendency to see the world in a more positive manner as mindfulness meditation is shown to support positive reappraisal [1] [12]. The current research showed satisfactory internal reliability of the scale (Cronbach's α = 0.91).

Depression Anxiety Stress Scale (DASS; meditation-VR group, mean = 1.62, SD = 0.34, relaxation-VR group, mean = 1.81, SD = 0.35, meditation-no VR group, mean = 1.83, SD = 0.56, and relaxation-no VR group, mean = 1.70, SD = 0.31). The scale was prepared to detect the level of depression as a state and anxiety in a patient [32]. Polish translation has been commonly used for example to assess the emotional states of women with pregnancy pathologies [26]. Our hypothesis is that participants scoring higher in mindfulness meditation as a state should have a general tendency towards lower results in the DASS. The scale consists of 21 questions with three subscales: anxiety, depression and stress; answers indicating how often participants feel in a certain way from „never" to „almost always"; it has been shown to have a high level of internal reliability (Cronbach's α = 0.91)

Satisfaction With Life Scale (SWLS; meditation-VR group, mean = 4.28, SD = 1.60, relaxation-VR group, mean = 4.03, SD = 1.28, meditation-no VR group, mean = 3.69, SD = 1.31, and relaxation-no VR group, mean = 4.13, SD = 1.07).The scale has been developed to measure self-evaluation of general life satisfaction and to continue the wide research on subjective well-being [33], translated to Polish in 2015 by Jankowski [20]. It is a 5-item scale using a 7-point response, from strongly disagree to strongly agree. In our research, the hypothesis was that the scale should correlate positively with TMS. The level of internal reliability is high (Cronbach's α = 0.9).

Identity With All Humanity Scale (IWAH; meditation-VR group, mean = 3.10, SD = 0.69, relaxation-VR group, mean = 2.99, SD = 0.82, meditation-no VR group, mean = 3.23, SD = 0.83, and relaxation-no VR group, mean = 3.03, SD = 0.79). This scale was developed by McFarland, Webb, and Brown [40] to measure humanitarian concerns. It consists of 9-items asking participants about their identification with all humanity as a whole (e.g. „How close do you feel to people all over the world?"). The measure is linked to people's interest in international humanitarian actions. It was translated into Polish for the purpose of the study, with satisfactory internal reliability (Cronbach's α = .87). As the case study presents, long-term meditation practices can lead to body boundary dissolution and

subsequently loss of the egocentric perspective [2], hence we assumed even a short meditation may lead to the loss of social identity while enforcing the sense of identity with all humanity. The hypothesis is that meditators should have higher results in the IWAH scale than the relaxation group.

Interpersonal Reactivity Index (IRI; meditation-VR group, mean = 3.23, SD = 0.40, relaxation-VR group, mean = 3.25, SD = 0.55, meditation-no VR group, mean = 3.32, SD = 0.42, and relaxation-no VR group, mean = 3.40, SD = 0.40). The commonly used questionnaire of 28 items (responses on a scale from 1 „[this sentence] does not describe me at all" to 5 „[this sentence] describes me very well") was developed to measure empathy on four subscales: FS – Fantasy Scale; EC – Empathic Concern; PT – Perspective Taking; PD – Personal Distress (Davies, 1980) [8][9]. A Polish translation has been used for the research on empathy with satisfactory results of internal reliability [21]. We decided to use the same test as it is a well-studied tool that takes into consideration emotional (PD and EC) and cognitive aspects of empathy (FS, PT). The mutual influence of empathy and mindful meditation is also widely studied in neuroscience [23] proving that there are some significant outcomes of intense contemplative training of compassion or empathy on subjective rating of the negative effects while watching a number of highly stressful movies. Hence, the hypothesis is that those who meditated would score higher on IRI, especially in PD and EC as these two are mostly related to meditation training, than the participants who relaxed their muscles only. The measure had a satisfactory level of internal reliability (Cronbach's α = 0.82, with the 21st item excluded as it had a negative correlation with the total scale; with 95% confidence intervals).

TABLE II. SAMPLE CHARACTERISTICS AND CHI-SQUARE ANALYSIS FOR METRIC DATA SUCH AS GENDER, EXPERIENCE WITH VR AND EXPERIENCE WITH MINDFULNESS MEDITATION IN RELATION TO MINDFULNESS VS. RELAXATION CONDITIONS.

		Total, *N* = 80	M*	R**	χ^2	*Df*	*p*
Gender	Female	58	55	63	0.21	1	0.65
	Male	42	45	37			
VR experience	None	54	58	40	4.33	3	0.23
	Some	46	42	40			
Frequency of meditation practice	None	26	25	27	0.00	1	1
	Some	74	75	73			

* Mindfulness condition, *n* = 40.
** Relaxation condition, *n* = 40.

TABLE III. SAMPLE CHARACTERISTICS AND CHI-SQUARE ANALYSIS FOR METRIC DATA SUCH AS GENDER, EXPERIENCE WITH VR AND EXPERIENCE WITH MINDFULNESS MEDITATION IN RELATION TO VR VS. NO VR.

		Total, *N* = 80	VR, *N* = 40	No VR, *N* = 40	χ^2	*df*	p
Gender	Female	59	50	67	1.86	1	0.17
	Male	41	50	33			
VR experience	None	54	52	55	0.00	1	1
	Some	46	48	45			
Frequency of meditation practice	None	26	17	35	2.32	1	0.13
	Some	74	83	65			

An even number of 80 participants enrolled in the study. The average age was 36.2, ranging from 25 to 61, with 33 males and 47 females. Participants were employees of the National Information Processing Institute and all of them were Polish. The study was advertised as an opportunity to explore virtual technology in the workplace. Participants were questioned about their experience of VR as well as their experience of meditation, including different kinds of meditation, and their age. 27 of them had no experience of any kind of meditation. The frequency of those who meditated also differed: 6 of them meditated daily while 15 meditated at least once a week with one person meditating 120 minutes daily. The rest of them rarely meditated or meditated only a few times a month. The VR experience divided the participants into four subgroups: those with no experience (55%), those who had used VR once (25%), those who had used it but rarely (16.25%) and those who used it often (3.75%).

In order to validate adequate randomization of our participants, we used Chi Square tests. We found that there were no significant interactions for either mindfulness vs. relaxation conditions, or VR vs. no VR conditions. The details can be found in Table II and Table III.

V. RESULTS

Our study was conducted to examine the three main hypotheses. The first one was that VR would enhance the effects of both (mindfulness and relaxation) training sessions, and this would be expressed through the feelings of general happiness and openness to personal experiences under VR vs. no VR conditions, especially under mindfulness conditions. Using two-way ANOVA analysis, we found no proof for the hypothesis. There was no significant effect of VR conditions on the dependent variables: for the TMS ($F(1,76) = 1.09$, $p = 0.30$), the POS

($F(1,76) = 0.01$, $p = 0.92$), the DASS ($F(1,76) = 0.30$, $p = 0.59$) and the SWLS ($F(1,76) = 0.68$, $p = 0.41$). The interaction effect of independent variables is not significantly related to the results on TMS ($F(1,76) = 1.02$, $p = 0.32$) either.

TABLE IV. RESULTS OF A TWO-WAY ANOVA ANALYSIS WITH TORONTO MINDFULNESS SCALE SCORES

Source	df	F ratio	P value
Mindfulness vs Relaxation	1	1.02	0.31
VR vs No VR	1	1.09	0.3
Interaction effect.	1	1.02	0.32

To check the effect of VR on subjective well-being we ran a two-way MANOVA and added the mood-related scales (the SOP, DASS and SWLS measures to the calculations): the main effect for the independent variables was not significant, $V = 0.02$, $F(3,76) = 2.17$, $p = 0.10$. Figure 4 presents the boxplots for TMS as a dependent variable and the two conditions, where the hypothesized tendency (the highest scores for meditation with VR group) is supported, however not significantly. The main effects for the TMS with the interaction effect on the 2x2 ANOVA are visible in Table IV.

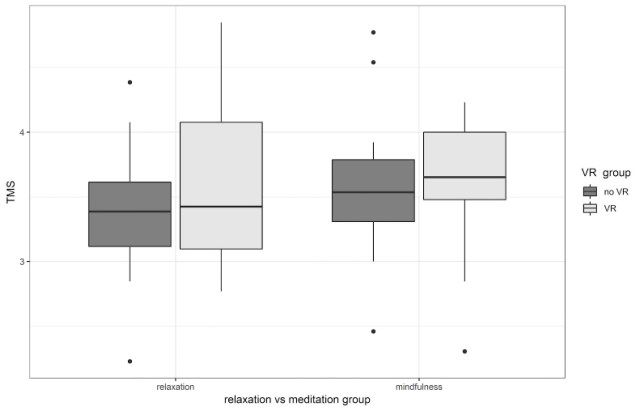

Figure 4. Boxplots for 2 x 2 experiment design.

TABLE V. MATRIX OF PEARSON'S CORRELATIONS FOR DEPENDENT VARIABLES.

	TMS	POS	DASS	SWLS	IRI	IWAH
TMS	1	.40**	.30**	-.05	.33**	.07
POS	.40**	1	-.26*	.62**	.23*	.38**
DASS	.30**	-.26*	1	-.44**	.25*	-.22*
SWLS	-.05	.62**	-.44**	1	.06	.24*
IRI	.33**	.23*	.25*	.06	1	.35**
IWAH	.07	.38**	-.22*	.24*	.35**	1

**. Correlation is significant at the 0.01 level.
*. Correlation is significant at the 0.05 level.

In order to check the external validity of the TMS as well as to further explore the possible explanations of the results, we measured the correlations between the dependent variables: TMS, POS, DASS, SWLS, IRI and IWAH. We found some correlations to be significant. The correlation matrix is displayed in Table V.

VI. DISCUSSION

A) Main hypotheses

The goal of the study was to check the potential influence and utility of Virtual Reality in contemplative training and to compare the effects of mindfulness training and relaxation training.

We hypothesized that VR conditions would enforce the results of mindfulness through immersion since Virtual Reality has been shown to support immersion in the digital world. This might help to create a safe but reliable experimental environment [7]. We found no proof for the hypothesis, undermining the potential of VR to achieve alternative states of mind. The results of ANOVA under VR conditions were not significant either as a main effect or as an interaction effect between both mindfulness and VR conditions. MANOVA analyses revealed a similar lack of significant results taking into consideration several dependent variables: TMS, POS, SWLS and DASS.

It was hypothesized that both meditation training sessions (with or without VR) would enhance the subjective well-being of participants more than the relaxation training. We assumed that mindfulness training would boost subjective well-being as well as decentration and curiosity of one's emotions more than relaxation. This would be observable via higher scores on the Mindfulness Toronto Scale (measuring curiosity and decentering), the Positive Orientation Scale (measuring general positive attitude to life), the Satisfaction With Life Scale and lower the results of the Depression Anxiety Stress Scale. The assumption is based on the research on mindfulness training: decentering is known to be a central characteristic of mindfulness but not of relaxation [11]. Mindfulness, on the other hand, is related to positive reappraisal and stress-coping processes along with other mindfulness-typical processes, e.g., attentional broadening [13]. However, there were no conclusive results to indicate that the mindfulness meditation group scored significantly higher than the relaxation group: the two-way ANOVA analysis revealed no significant main effects of mindfulness training vs. relaxation training. Also, MANOVA analyses, taking into consideration more than one dependent variable, showed no more statistically significant effects under mindfulness/relaxation conditions.

We also hypothesized that this mindfulness-related increase in general happiness and curiosity along with decentration would have an impact on social skills, such as

empathy or group identity. This would be expressed in higher results of the Interpersonal Reactivity Index as well as of the Identity With All Humanity scale, as mindfulness has been proved to enhance social processing on various levels, e.g.. implicit bias [28]. However, we failed to prove this hypothesis. Our results showed no influence of either mindfulness meditation conditions, or of the interaction of both conditions on the two dependent variables related to social processing. In all of our calculations, we rejected a possible interference of demographic data proving well-randomized groups.

B) Possible explanations – mindfulness training

Since the results of experimental manipulation were not significant on any of the dependent variables, we may think of methodological errors that appeared in the study and should be taken into consideration in following studies. One of the possible objections against the study design was the briefness of the mindfulness training. Some researchers in contemplative studies argue that mindfulness is a complex and yet mostly unknown state [16]. We could conclude that a short intervention may not be sufficient to tackle such a complex alternative state of mind. On the other hand, one can argue that even shorter training sessions have already been successfully applied to meditation training with some significant outcomes [27], especially since TMS as a tool has been designed in such a way that it would capture the instant mental processes related to mindfulness (e.g., "I was curious to see what my mind was up to from moment to moment"). Moreover, the length of the training was exactly the same as the length of the training used in the TMS validation [25].

C) Possible explanations - self-reported measures

There is a growing body of evidence which suggests behavioral measurements give a better evaluation of the effects of mindfulness training than self-reported measures [16][17]. This strong objection is based on several issues, e.g., not having a clear definition of what mindfulness really is; self-reported measures not being able to tackle the profound correlations of mindfulness as well as not being able to capture the exact meaning of certain understandings of Buddhist teachings. However, in our research we have not only failed to prove TMS to be influenced by the experimental conditions but also other dependent variables seemed to be inexplicable by the experiment itself. In order to ensure that the lack of main effects or interactions is not related to gender, experience with VR or experience with meditation, we ran Chi-Square analysis that proved the factors were equally distributed over the groups. We decided to compare the dependent variables using Pearson's correlations in order to explore the lack of significant results. Surprisingly, there was a significant positive relation of TMS to the positive mood scale (POS) and the depression and anxiety-related scale (DASS). There was also a significant, positive correlation with the IRI but not with the IWAH scale, even though there was a significant, positive correlation between the last two variables. It is important to note, however, that there was only one average significant correlation (POS and SWLS; measures related to positive mood and life-satisfaction), with the rest of the correlations being weak or insignificant. These results may support our conclusion that maybe the self-related measures are not strong enough to efficiently measure the effects of such a complex process as mindfulness.

D) Possible explanations – VR design

An interesting aspect of the measurement that has not been reported is the spontaneous reaction of participants when exploring the VR meditation island. While conducting the study, we observed that participants paid particular attention to those details of VR that did not exactly match reality. Looking at the general research where VR is proposed to be a meditation-friendly environment, some of the virtual worlds had some similar features, e.g., a lake, trees, forest sounds (e.g., [31]) and they seemed to imitate a natural background. However, there were exceptions, e.g., [24], where the same objects (a tree, a lake, a piece of land, sunny weather) were constructed in the simplest way possible, instead of trying to imitate nature. We hypothesize that in such a way, participants acknowledge the differences between VR and the real world, yet they do not focus on the detailed differences between these two worlds, since they are trivial. Hence, for the next study, we suggest an environment that would symbolically resemble the natural environment rather than try to imitate it. We suggest this way may facilitate immersion through familiarizing participants to an imperfect world and letting them focus on the purpose of the study, rather than encouraging them to seek the hidden imperfections of a virtual world. On the other hand, we conceptualize that maybe even a predictable but very abstract environment could cause the same immersion without absorption by the imperfections of the world. In such a way, the virtual world would be obviously unrelated to the natural landscapes, but would still remain predictable, hence it could be a secure place to meditate in.

Analyzing the effects of mindfulness, self-transcendence is an often-omitted construct. Following the potential importance of transcendence in mindful meditation, it is crucial for future research using VR to take it into consideration. The authors of the *Mindfulness-To-Meaning Theory* [12] argue that self-transcendence is a natural effect of mindfulness meditation as it brings pleasurable emotions such as gratitude or compassion. It also lifts meditators to the next steps of meditation, the feeling of oneness, selflessness, and finally to the non-dual sense of subject-object relations. We hypothesize that maybe certain landscapes can facilitate the feeling of self-transcendence through a wide clear view, and hence the role of VR in self-transcendence should be carefully taken into consideration in future studies.

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Finally, it should also be mentioned that maybe VR is not an effective or sufficient tool to enhance mindfulness experiences. We hypothesize that it could be a beneficial tool in promoting relaxation (i.e., through immersion) but not sufficient to enhance more complex mental states related to mindfulness such as decentration or non-judgmental observation of one's thoughts and emotions. Even the feeling of transcendence can be blurred by the virtual experience bringing a state of excitement or curiosity of the outside world rather than helping to understand the internal states leading to alternative states of awareness.

E) Generalization and study limitations

The study is not free from some limitations typical to the field of mindfulness, e.g., the effectiveness of a brief mindfulness training session remains questionable. On the other hand, we managed to develop a study of interest to VR enthusiasts and not only meditation enthusiasts – which is a common sampling problem since meditation may seem attractive to a very distinct group of people. Yet, another challenge stems from the fact that all the participants were Polish and the cultural upbringing might have influenced the results. Taking into consideration that mindfulness is relatively new in Poland (Polish Mindfulness Society was inspired by Jon-Kabat Zinn and developed in 2008; [19]), it is certainly important to compare the results controlling for cultural influences. Last but not least, individual differences could have affected the results of the study. We suggest adding some questionnaires related to openness to experience and neuroticism to the study in the future. Due to limited external validity as well as to a specific sample quality, we cannot generalize the results for a wider population.

VII. CONCLUSIONS

To sum up, our study failed to prove the main hypothesis - that even short mindfulness meditation can enhance subjective well-being along with decentration and curiosity to one's internal states, and in effect, it can also influence social skills such as empathy. Another hypothesis, that Virtual Reality would boost the effect of mindfulness, also failed. We found a few possible methodological explanations, i.e., that the mindfulness/relaxation training period could have been too short and brief. However, as some previous studies proved, even a short mindfulness intervention can be effective in the aforementioned states. We hypothesized that the virtual environment should be distinctively different from the real environment so participants can focus on their tasks, instead of directing attention to the imperfections of the virtual world. Following the comments of contemplative science, we also discussed the drawbacks of self-reported measures in studying such a profound state as mindfulness. Certainly, before we finally establish the role of mindfulness in human life, and the effect of Virtual Reality on it, some further evidence needs to be collected.

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